

Research Report:

The Beneficial Effect of Concurrent Task-Irrelevant Mental Activity on  
Temporal Attention

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## Abstract

It is believed that the human cognitive system is fundamentally limited in deploying attention over time. This is reflected in the attentional blink, the impaired ability to identify the second of two visual targets presented in close succession. We report the paradoxical finding that the attentional blink is significantly ameliorated when observers are concurrently engaged in distracting mental activity, such as free association on a task-irrelevant theme, and listening to music. This questions the fundamental nature of the attentional blink, and suggests that the temporal dynamics of attention are determined by task circumstances that induce either a more or a less distributed state of mind.

Human attention is limited. This is apparent in everyday life, for example when driving while talking on the phone (McKnight & McKnight, 1993), and in the laboratory, for example when observers fail to detect a visual stimulus while simultaneously having to discriminate a tone (Arnell & Jolicoeur, 1999; Kahneman, Beatty, & Pollack, 1967; Pashler & Johnston, 1989). Apparently, the one type of mental activity interferes with, distracts, or takes attentional capacity away from the other (Kahneman, 1973; Pashler, 1984; Welford, 1952).

Exceptions to such limitations have been reported. For example, playing the piano and typing suffer little from concurrently having to shadow a list of words (Allport, Antonis, & Reynolds, 1972; Shaffer, 1975). Furthermore, after extensive practice, some individuals are able to copy spoken sentences while at the same time reading other material with only slight lapses in accuracy (Hirst, Spelke, Reaves, Caharack, & Neisser, 1980; Spelke, Hirst, & Neisser, 1976). Interestingly, professional golfers actually improve their putting performance while simultaneously performing an auditory discrimination task instead of fully concentrating on playing golf (Beilock, Carr, MacMahon, & Starkes, 2002). However, note that in these cases the primary task generally involves highly practised or automated procedural skills that make step-by-step attentional control unnecessary or sometimes even harmful.

Here we report the beneficial effect of task-irrelevant mental activity on performance in a task that does not involve automated procedural skills, but instead relies heavily on paying attention to visual input. In the version of the task as used here (illustrated in Figure 1, see the Method section for details), trials consist of a series of letters presented rapidly at the center of the display. Among the letters are two target digits (referred to as T1 and T2), and the observer's task is to report these at the end of each trial. The usual result is that detection of T2 suffers considerably if it is presented within a short lag from T1 (typically 500 ms), a phenomenon referred to as the attentional blink. The

general explanation is that processing of T1 takes up limited attentional resources. For T2, access to these resources is then either denied, or its representation is so vulnerable that it easily suffers from interference from temporally surrounding distractor letters (Broadbent & Broadbent, 1987; Chun & Potter, 1995; Raymond, Shapiro, & Arnell, 1992; Shapiro, Arnell, & Raymond, 1997).

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Insert Figure 1 about here

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The present work was motivated by participants in previous experiments, who, rather counterintuitively, reported improved T2 performance when being somewhat unfocused on the task. For what it was worth, our own introspection also suggested that the task was best done in a “slightly distracted state of mind”. To test this idea, we recruited four groups of participants, whose primary task was to detect the two digits in the stream of letters. In the standard control group, in addition to the explanation of the task, participants received the type of instruction that is standard for this and related kinds of experiments, namely to concentrate and report as many targets correctly as possible. In the first experimental group – the free association group – participants were instructed to think about either their most recent holiday or their shopping requirements for an imaginary dinner with friends, while doing the task. No mention was made of the need to concentrate or to report as many digits correctly as possible. If T2 detection indeed improves under distracting conditions, we would expect an increase in performance here. To further test the idea that a moderate amount of distraction may actually improve performance on the attentional blink task, observers in the listen to music group performed the task while listening to a rhythmical tune. In one

block they were asked to just listen. In another block they were given the additional task of detecting an occasional yell that was part of the tune.

An alternative explanation for an improvement would be that the somewhat funny instructions or the presence of music may have contributed to a higher appreciation of what would otherwise have been a boring experiment, resulting in overall more motivation for the task. To test for this, the reward group received payments according to their performance (Bahrick, Fitts, & Rankin, 1952; Lewis & Linder, 1997).

## Methods

Participants. Sixty-six randomly assigned healthy subjects with normal or corrected-to-normal vision participated: 17 in the standard condition (10 male, average age 22 years); 17 in the free association condition (9 male, average age 21 years); 16 in the listen to music condition (5 male, average age 20 years); 16 in the reward condition (6 male, average age 21 years). None of the participants was aware of other conditions than the one he or she was placed in. There were no significant effects involving sex (all  $F_s < 1.5$ ).

Stimuli. Stimulus generation and response recording were done using E-Prime (Psychology Software Tools, Inc., Pittsburgh, PA). The stimuli and task were the same in all conditions, unless stated otherwise. A  $0.5 \times 0.5^\circ$  (visual angle) fixation cross was presented for 1000 ms in the center of the display, and subsequently replaced by a rapid serial presentation of 13 to 21 letters, each measuring approximately  $0.8 \times 0.8^\circ$ . Each letter was randomly drawn (without replacement) from the alphabet and presented for 88 ms, followed by a 32 ms blank. “T”, “O”, “Q”, and “S” were left out as they

may resemble digits too much. On each trial, two of the letters were replaced with digits, randomly drawn (without replacement) from the set 2 to 9. The second digit (T2) was presented 3 to 6 temporal positions from the end of the stream. The temporal distance between the first digit (T1) and the second (T2) was systematically varied from 1 to 5 items, corresponding to lags of 120, 240, 360, 480, and 600 ms. All stimuli were presented in black on a gray (16 cd/m<sup>2</sup>) background.

Procedure. The participant's task was to identify both T1 and T2. An unspeeded response was made at the end of each trial by typing in the digits in order on a standard keyboard. Each erroneous response was immediately followed by negative feedback stating, in red, "No, it was #", with # being the correct digit. Participants were instructed to guess whenever they failed to identify a digit. After 500 ms a new trial started. The experiment started with 10 practice trials, followed by two blocks of 100 trials, resulting in a total of 40 trials per lag which were randomly mixed. The experiment lasted approximately 25 minutes, and participants were paid 4 euro (except in the reward condition, see below). In the standard condition, each block was preceded by the usual instruction to concentrate on the task and report as many digits as possible. In the free association condition, participants were invited to think about their holidays (in one block) or about their shopping plans for a dinner with friends (in the other block, with block order counterbalanced across participants), while doing the task. It was mentioned that they could freely associate from these themes and return to these themes if they could no longer think of something else. In the listen to music condition, participants were presented (through a set of headphones) with a continuous rhythmical tune running at 120 beats per minute. In this experiment the start of the visual stimulus (i.e., the fixation cross) was synchronized with the start of the musical measure. Note that the presentation of the letters and digits was not synchronized with the beat. In one block, participants were asked to just listen to the beat

while doing the task. In the other block (again block order was counterbalanced), they were asked to detect an occasional yell that was part of the music (there were no other verbal elements in the music). If a yell occurred during a trial, as was the case on 15%, the task was to type in two capital Xs instead of the digits. These trials were included to make sure that participants indeed listened to the music. These trials were excluded from any analysis. Note however, that, because participants received 15% more trials in this experiment, any improvements in performance may have been due to their longer experience with the task. To check this, we conducted the same statistical analyses with the last 15% of the trials removed. This made no difference to the results whatsoever (even numerically there was hardly a difference). Finally, in the reward condition, participants were paid according to their performance, with a minimum of 3 euro. For each correct identification, their earnings increased by 1 eurocent. For each incorrect identification, earnings decreased by 3 eurocents. Thus, the maximum possible earnings were 7 euro (3 euro plus 200 trials times 2 identifications per trial). The earnings were updated and shown after every response, together with the feedback text mentioned above. In all conditions, all instructions were automated and presented onscreen. Apart from initial set-up and final payments, there were no interactions with the experimenter, who was a lab assistant naive to the main purpose of the experiments.

## Results and Discussion

Figure 2 shows the average T1 and T2 detection accuracy for all groups, as a function of the lag between T1 and T2. Note that we report T2 accuracy averaged across all trials. However, the same pattern of results was found for T2 accuracy contingent upon correct T1 report. An omnibus ANOVA on T1 accuracy revealed a trend towards a main effect of lag,  $F(4,248) = 196.69$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.760$ , a trend towards a main effect of group,  $F(3,62) = 2.30$ ,  $p = 0.087$ ,  $\eta_p^2 =$

0.100, and a trend towards a group x lag interaction,  $F(12,248) = 1.65$ ,  $p = 0.079$ ,  $\eta_p^2 = 0.074$ .

The same ANOVA, but now on T2 accuracy, showed all main effects and interactions to be significant; lag,  $F(4,248) = 55.85$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.474$ ; group,  $F(3,62) = 6.4$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.237$ ; and group x lag,  $F(12,248) = 5.06$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.197$ .

The diamond symbols in Figure 2 show the average performance in the standard group. As can be clearly seen, T2 detection suffers considerably for almost all lags. An exception is lag 1, where T2 detection is quite good – a phenomenon that is referred to as “lag 1 sparing” (Potter, Chun, Banks, & Muckenhoupt, 1998). The results are typical for the attentional blink. Note further that T1 detection is quite poor for lag 1. The close temporal proximity of T1 and T2 may lead to both being perceived, but in the wrong order. This way, participants may enter T2 first (leading to a T1 error), but upon receiving negative feedback, enter T2 again (now correctly as T2) as they realized they got the order wrong (Chun & Potter, 1995).

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Insert Figure 2 about here

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Interestingly, in the free association group (in which participants were instructed to think about their holiday or shopping requirements), T2 detection performance was overall significantly better than in the standard group,  $F(1,32) = 4.60$ ,  $P < 0.05$ ,  $\eta_p^2 = 0.126$ . There was no improvement for lag 1, leading to a group x lag interaction,  $F(4,128) = 4.36$ ,  $P < 0.01$ ,  $\eta_p^2 = 0.120$ . Note that T1 detection performance did not suffer in the free association group ( $F < 1$ ). This is important as it excludes an account stating that our instructions simply led to a shifting of attentional

resources from T1 to T2. Fewer T1 detections may have led to fewer trials on which a blink occurred and hence better T2 detection (Chun & Potter, 1995). However, Figure 2 clearly shows that T1 detection did not deteriorate.

The listen to music group completed two types of blocks, one in which they just listened to the tune, another in which they had to detect a yell in the same tune. In the latter type of block, they detected 96% of the yells. However, performance did not differ between the “yell” and “no yell” blocks and we present them as one here. Figure 2 again shows a dramatic improvement in T2 detection in this condition, relative to the standard condition,  $F(1,31) = 17.01$ ,  $P < 0.001$ ,  $\eta_p^2 = .354$ . The improvement occurred across all lags (except lag 1, resulting in a group x lag interaction,  $F(4,124) = 11.20$ ,  $P < 0.001$ ,  $\eta_p^2 = .265$ ) and was such that the attentional blink virtually disappeared. As can be seen from the top panel of Figure 2, this was not attributable to decreased T1 performance. On the contrary, T1 detection slightly improved too,  $F(1,31) = 7.91$ ,  $P < 0.01$ ,  $\eta_p^2 = .203$ . The improvement indicates that T1 performance was generally not at ceiling in the previous conditions.

Contrary to a general increased motivation account, the reward group did not show any notable improvement in T2 detection from that in the standard condition ( $F < 1$ ), except for a slight trend towards better performance at the longest lag,  $t(31) = 1.41$ ,  $P = 0.084$  (one-tailed). This would suggest that the duration, but not the magnitude of the blink may be reduced under conditions of higher motivation.

## General Discussion

The results show that performance on an attentionally demanding visual detection task may improve when accompanied by task-irrelevant mental activity. This suggests that, under rapid visual presentation conditions, target detection may benefit from a more diffuse attentional state. There are several ways in which a more diffuse attentional state may be induced by the present experimental manipulations. First, the effects may be related to arousal. It is well known that overall arousal levels modulate attentional focusing (Aston-Jones, Rajkowski, & Cohen, 2000; Easterbrook, 1959; Kahneman, 1973; Yerkes & Dodson, 1908). Under normal circumstances, arousal levels may be set such that they allow for efficient focusing on T1, but to the exclusion of T2. By decreasing or increasing arousal (as may be the case in the free association and music conditions), the attentional system becomes more susceptible to other input, including T2. Second, thinking about one's holiday or listening to music may induce a positive affective state, something which has been shown to improve performance on several cognitive tasks, especially those requiring a broader, more flexible operating mode (Ashby, Isen, & Turken, 1999). This would also explain the slight overall improvement on T1 performance in the music condition. A third and more cognitive explanation is that it is actually the additional task itself that induces a more distributed state of attention. As attention widens to incorporate the extra task, it may also widen temporally and thus include the second target in the RSVP stream.

In conclusion, our results show that providing some distraction (either through instruction to think about something else or through music) causes considerable improvements in detecting visual targets in a rapidly presented stream of items. These results have important implications for research on the attentional blink and related phenomena. Not only should we continue our attempts to increase our understanding of the functional and neural mechanisms underlying the blink; an additional

challenge will be to determine how this phenomenon interacts with the general mental state of the observer.

### Acknowledgements

This research was supported by the Netherlands Organization for Scientific Research (C.O. and S.N.). We thank Patrick van Olfen for his assistance in collecting the data.

## References

- Allport, A., Antonis, B., & Reynolds, P. (1972). On the division of attention: A disproof of the single-channel hypothesis. Quarterly Journal of Experimental Psychology, *24*, 225-235.
- Arnell, K. M., & Jolicoeur, P. (1999). The attentional blink across stimulus modalities: Evidence for central processing limitations. Journal of Experimental Psychology-Human Perception and Performance, *25*(3), 630-648.
- Ashby, F. G., Isen, A. M., & Turken, A. U. (1999). A neuropsychological theory of positive affect and its influence on cognition. Psychological Review, *106*, 529-550.
- Aston-Jones, G., Rajkowski, J., & Cohen, J. D. (2000). Locus coeruleus and regulation of behavioral flexibility and attention. Progress in Brain Research, *126*, 549-554.
- Bahrick, H. P., Fitts, P. M., & Rankin, R. E. (1952). Effect of incentives upon reactions to peripheral stimuli. Journal of Experimental Psychology, *44*, 400-406.
- Beilock, S. L., Carr, T. H., MacMahon, C., & Starkes, J. L. (2002). When paying attention becomes counterproductive: Impact of divide versus skill-focused attention on novice and experienced performance of sensorimotor skills. Journal of Experimental Psychology: Applied, *8*, 6-16.
- Broadbent, D. E., & Broadbent, M. H. P. (1987). From detection to identification: Response to multiple targets in rapid serial visual presentation. Perception & Psychophysics, *42*, 105-113.
- Chun, M. M., & Potter, M. C. (1995). A two-stage model for multiple detection in RSVP. Journal of Experimental Psychology: Human Perception and Performance, *21*, 109-127.

- Easterbrook, J. A. (1959). The effect of emotion on cue utilization and the organization of behavior. Psychological Review, 66, 183-201.
- Hirst, W., Spelke, E. S., Reaves, C. C., Caharack, G., & Neisser, U. (1980). Dividing attention without alternation or automaticity. Journal of Experimental Psychology: General, 109, 98-117.
- Kahneman, D. (1973). Attention and effort. Englewood Cliffs, NJ: Prentice-Hall.
- Kahneman, D., Beatty, J., & Pollack, I. (1967). Perceptual deficit during a mental task. Science, 157, 218-219.
- Lewis, B. P., & Linder, D. E. (1997). Thinking about choking? Attentional processes and paradoxical performance. Personality and Social Psychology Bulletin, 23, 937-944.
- McKnight, A. J., & McKnight, A. S. (1993). The effect of cellular phone use upon driver attention. Accident Analysis and Prevention, 25, 259-265.
- Pashler, H. (1984). Processing stages in overlapping tasks: Evidence for a central bottleneck. Journal of Experimental Psychology: Human Perception and Performance, 10, 358-377.
- Pashler, H., & Johnston, J. C. (1989). Interference between temporally overlapping tasks: Chronometric evidence for central postponement with or without response grouping. Quarterly Journal of Experimental Psychology, 41A, 19-45.
- Potter, M. C., Chun, M. M., Banks, B. S., & Muckenhoupt, M. (1998). Two attentional deficits in serial target search: The visual attentional blink and an amodal task-switch deficit. Journal of Experimental Psychology-Learning Memory and Cognition, 24(4), 979-992.
- Raymond, J. E., Shapiro, K. L., & Arnell, K. M. (1992). Temporary suppression of visual processing in an RSVP task: An attentional blink? Journal of Experimental Psychology: Human Perception and Performance, 18, 849-860.

- Shaffer, L. H. (1975). Control processes in typing. Quarterly Journal of Experimental Psychology, 27, 419-432.
- Shapiro, K. L., Arnell, K. M., & Raymond, J. E. (1997). The attentional blink. Trends in Cognitive Sciences, 1, 291-296.
- Spelke, E. S., Hirst, W., & Neisser, U. (1976). Skills of divided attention. Cognition, 4, 215-230.
- Welford, A. T. (1952). The 'psychological refractory period' and the timing of high-speed performance - a review and theory. British Journal of Psychology, 43, 2-19.
- Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. Journal of Comparative Neurology of Psychology, 18, 459-482.

## Figure captions

Figure 1. Outline of the basic paradigm. On every trial, between 13 and 21 items were presented at the center of the screen, preceded by a 1000 ms fixation cross. Most of the items were letters, presented for 88 ms each, followed by a 32 ms blank (resulting in 120 ms between different items). Among the items were two target digits (T1 and T2), which observers had to report at the end of the trial. The interval between T1 and T2, referred to as “lag”, varied from 1 to 5 temporal positions (i.e. from 120 ms to 600 ms).

Figure 2. Average detection accuracy (%) for the first (T1, top panel) and second (T2, bottom panel) of two digit targets in a rapid serial visual stream of letters. Error bars denote one standard error of the mean. Note the reduced dip in T2 performance (“attentional blink”) for the free association and listen to music conditions relative to the standard and reward conditions.



